ROAD FLOOD WARNING SYSTEM

Yiu K Yung, Senior Engineer, Queensland Department of Main Roads
Floor 24, 41 George Street, Brisbane, QLD 4001, AUSTRALIA
Phone: +61 7 34043401
Fax: +61 7 34043833
Email: yiu.k.yung@mainroads.qld.gov.au

ABSTRACT

The Road Flood Warning System provides predictive road flooding information on Queensland river crossings. The system obtains river height forecasts from the Bureau of Meteorology. It generates predictive information based on a set of pre-determined river height criteria of the concerned roads. The system improves the current road closure process by providing timely alerts for traffic managers to respond. At the locations that the Bureau does not monitor, regression and artificial neural network technology are used to correlate local condition with upstream river height stations. Predictive information is to be published in the Internet and used to activate roadside advisory devices as the additional elements to the existing traveller information service.

INTRODUCTION

In regional and rural Queensland, most of the big floods occur in summer or early autumn in association with tropical cyclones or intense monsoonal depressions. These systems can produce large quantities of rainfall - as much as 1,000 mm in a few days and result in widespread flooding. On average, it is expected that between four to six cyclones of different levels of severity would affect Queensland each year.

A possible consequence of flooding is road closures. These closures cause delays and detours. They also disrupt the vital flow of people and goods to and from regional communities and restrict access to essential services. Motorists can be stranded for days without knowing when the affected road will be reopen. In extreme cases of flooding, lives are put at risk. For example, in March 1990, a major flood developed in the lower Herbert River and Tully River in association with Cyclone "Ivor". The townships of Ingham and Halifax on the Herbert River were isolated. A bus full of passengers narrowly averted disaster when caught in 1.5 metre floodwaters on the Bruce Highway just north of Ingham (1).

In response to a need to improve the quality and timeliness of information on road closures due to flooding Queensland Department of Main Roads (QMR) and RACQ jointly developed and successfully implemented an improved traveller information service in 1999/2000. The service consists of an upgraded Internet website (2) and a dedicated telephone number using Interactive Voice Response (IVR) technology. The service provides reports on the current road closure status at about 300 flood prone locations in Queensland.

NEED FOR A REAL TIME SYSTEM

One of the limitations of the current system is the delay experienced in this manual but mandatory verification process. A road section may have been submerged for several hours before it is officially verified and closed. Motorists may be travelling on a road affected by flood without knowing the dangerous situation they are in. Another limitation of the current system is that it lacks the ability to alert motorists or QMR traffic managers of an imminent flood. Although motorists are advised of when a road has been closed they are not informed of the likely duration of that closure. This prevents them from planning for alternative routes.

It is anticipated that the availability of real-time and predictive information will provide QMR, as the road network manager, with sufficient time to respond to imminent flooding. It will also provide the opportunity for the automation of the road closure process. QMR is therefore committed to the development of a Road Flood Warning System (RFWS) focusing on river crossings in regional and rural Queensland where flooding causes serious transportation problem. Such an initiative has not been implemented elsewhere in Australia. QMR therefore submitted this project proposal to ITS-Australia as a Demonstration Project with the title of "Demonstration of the Application of ITS to Rural Areas".

REASONS FOR ROAD CLOSURE

Whether a road needs to be closed during flooding is influenced by two principles: Road users' safety and Road asset protection.

According to a research conducted by the former NSW Department of Public Work (3), vehicle stability during flooding is determined by two factors: the depth of water and the flow velocity that destabilises vehicles as a result of buoyancy. It was revealed that a vehicle becomes unstable when water is deeper than 0.3m, when flow velocity is greater than 2m/s, or when a linear combination of these factors exceeds a limit. The general rule is: the deeper the water level or higher the flow velocity, the more dangerous is the situation.

Complicating this issue is that different vehicle types can tolerate different water depth because vehicle axle heights and other physical characteristics are different. To simplify the implementation, RFWS adopts a conservative approach and treats all vehicles in the same manner.

From an asset protection point of view, flooding near a road may soften the soil under the road and cause structural weakness that could easily lead to damage if vehicles are allowed to use the road even if the road surface is not submerged yet. As different roads are constructed with different type of materials on different soil conditions, the depth of water that each road can tolerate are different.

WHAT IS A ROAD FLOOD WARNING SYSTEM

The Road Flood Warning System (RFWS) is a value-added flood forecasting information system for river crossings. It obtains river height forecast from the Bureau of Meteorology

(BOM) and transforms it into forecast relevant to the road. The forecast includes the timing when a river at a crossing would rise to a level that could affect the safety of motorists or the normal operation of the road, and the likely duration that the road would be affected. The system alerts QMR's traffic managers of an imminent flood so that sufficient time can be allowed to prepare for a response. After confirmation by QMR, information is transmitted to RACQ to be posted on its Traveller Information Web Site (2). By building RFWS on QMR's incident management system platform called STREAMS (Synergised Transport Resources Ensuring and Advanced Management System) which has the capability to control traffic signals and variable message signs (VMS), information can be disseminated to the roadside. Selected information can also be disseminated to subscribers through email and Short Message Service (SMS). Details of RFWS is discussed in the Methodology and System Overview sections.

METHODOLOGY

The existing Queensland flood telemetry network consists of more than 800 automatic river height stations and a number of rain gauges. These instruments are installed at critical locations, such as flood prone areas, to detect the current river height at these locations.

The flood forecast module in the RFWS has a number of forecasting models that simulate the hydro-dynamics at these locations. Each forecasting model is geographic dependent and therefore is unique. It takes river height and rainfall observations from sensors as input parameters to generate river height and flow rate forecasts in time-series format collectively called "hydrographs". By comparing the forecasts with the established road closure criteria, the time the road needs to be closed or reopened can be estimated. Traffic managers in QMR can be alerted in advance so that sufficient time is allowed to prepare a response.

It is worth-noting that flow velocity is neither measured nor forecasted in the existing Queensland flood telemetry network. Although flow velocity plays an important role in road closure criteria, a conservative approach of zero-submergence principle is adopted in RFWS as a compromise so that the relevance of this parameter becomes less significant.

In reality, it can be expensive to install and maintain a flood telemetry network that covers all the flood prone locations by purely installing equipment. A large number of flood prone locations do not and will not have any instrumentation at all. However, this problem can be resolved by a number of alternative solutions through the use of mathematics and information technology. This is based on empirical evidence that flooding will occur *some* hours after the upstream river height has exceeded certain level. By applying this relationship (correlation algorithm), flooding at a downstream location can be predicted based on the data collected at and predictions made for the upstream stations. This technique is purely a statistical response without involving hydrodynamic theory. However, the technique simplifies researchers' work by bypassing the need to develop complex hydrodynamic models.

Traditionally, linear / multiple regressions are popular tools to correlate upstream river heights with that at a downstream location. Recent development in artificial neural network technology (ANN) further simplifies the generation of correlation algorithms by using a computer to "train" itself up with historical data (4). This technology greatly reduces the time required to generate correlation algorithms and therefore has the potential to continually enhance the accuracy of the algorithms by means of more frequent or real-time 'training'.

SYSTEM OVERVIEW

The Queensland Department of Natural Resources (DNR) has installed and maintains a network of river height stations along major rivers supported by a number of rain gauges scattered within 12 river basins in Queensland. Observations at these stations are sent to the Flood Warning Centre in BOM (5) where they are processed. The automatic river height stations are either connected to the public telephone network and polled regularly by computer during periods of heavy rain, or communicate by radio and report at every one-millimetre change in river height to the local base stations.

It is understood that the Flood Warning Centre has developed forecasting models for the locations where the river height stations are installed. Refer to the "Forecasting model for location with sensors" block in Fig.1. The Centre also has "Correlation algorithms" (as shown in Fig. 1) for the locations where no instrumentation is installed so that forecasts for these locations can be made indirectly by using data observed at upstream stations. The modelling techniques are based on hydrology, regression and the use of neural network technology.
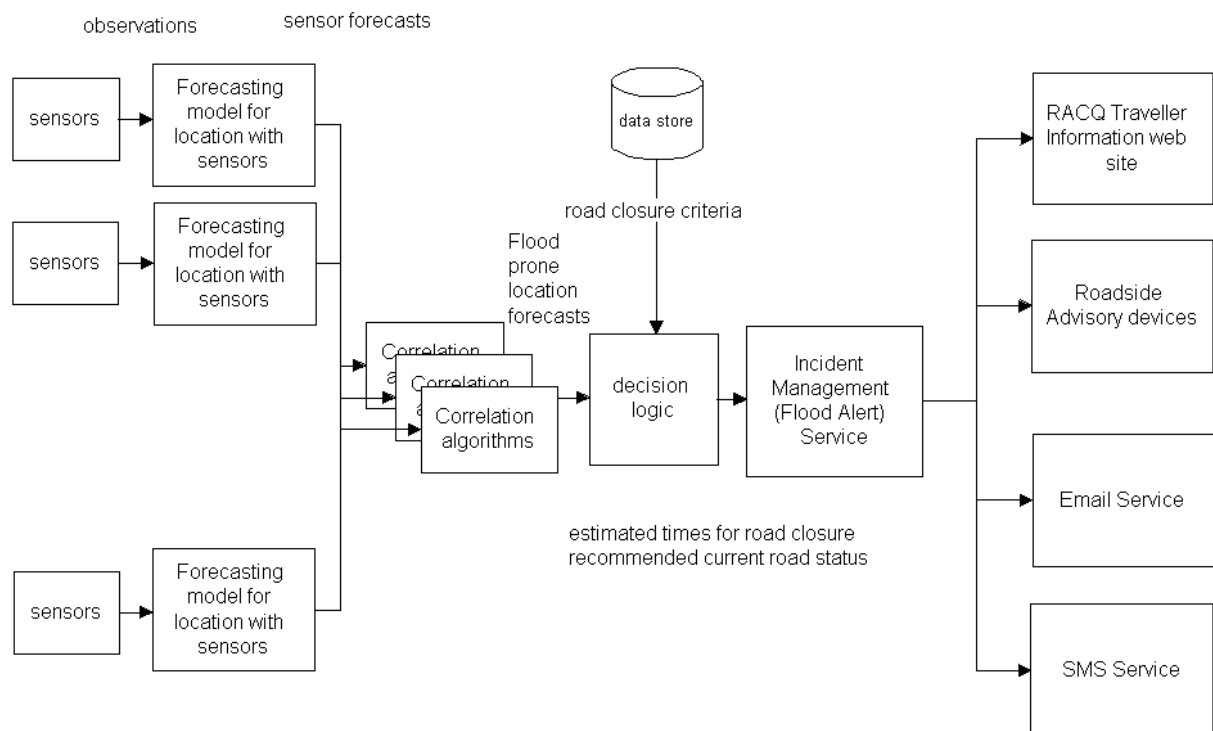

Fig. 1: RFWS Functional Block Diagram

QMR's involvement in this data collection and processing chain starts from the "Correlation algorithms" block in Fig. 1. QMR does not own any river height station for this purpose. Instead, QMR sources data from BOM. QMR's primary interest in this project is in road network management. However, some river crossings that QMR intends to monitor are not monitored by BOM. QMR therefore needs to develop "Correlation algorithms" for these locations. The techniques used by QMR to develop these algorithms are based on regression and the use of artificial neural network technology.

Conceptually, at the output end of the "Correlation algorithms" block in Fig. 1 is the river height forecasts called "hydrographs" for the flood prone locations that QMR intends to monitor. For a flood prone location that is monitored by BOM, the associated "Correlation algorithm" is simply a "straight-through" relationship. Otherwise, the algorithm may be a complex non-linear relationship with other stations in the same river basin with "*time*" introduced as an additional variable. The introduction of the "*time*" factor is due to the fact that it takes a finite time for water to travel from an upstream station to a downstream location.

Data Store contains the configuration data. For example: which flood prone locations are to be monitored, at what river-height level a crossing shall be closed and for how long in advance before road closure that the system should alert QMR's traffic managers.

The "Decision Logic" module works on hydrographs with the road closure criteria obtained from the Data Store to determine when a road is likely to be submerged, for how long it would be under water, when peak water level would occur and the peak water depth from the road surface.

The "Incident Management (Flood Alert) Service" module then determines whether to alert QMR's traffic managers. Traffic managers may configure the module to alert themselves some hours prior to the roads being submerged. Through interaction with traffic managers, this module assists in controlling roadside advisory devices such as traffic signals and variable message signs (VMS), sending up-to-date road closure forecast information to internal and external subscribers by email and SMS. After receiving the email alert, RACQ updates the Traveller Information Website (2) with the latest road closure status and forecast.

SYSTEM IMPLEMENTATION

Two implementations namely Pilot Implementation and Operational Implementation have been considered. The Pilot Implementation allows QMR to trial the concept whereas the Operational Implementation will be the final operational system. The merits of experimenting with the Pilot Implementation include:

- None or low impact to existing operation.
- Pilot Implementation offers a higher degree of control during experimenting period.
- Internet browsing softwares to be used by users in the Pilot Implementation are free.
- Shorter development time.

PILOT IMPLEMENTATION

The Pilot Implementation aims at an experimental system for QMR to trial the concept in a virtual operational environment prior to implementing an operational system. It adopts a "Client-Server" technique. It is a state-wide system making use of existing Internet technology but with reduced functionality. Traffic managers in every QMR Districts can access and edit data from a common Intranet server within QMR with Internet browsers. Traffic managers receive alerting emails from the server when a predefined river-height condition is reached. After the condition has been confirmed or the forecast has been edited,

traffic managers may authorise the transmission of the latest forecasts to internal / external subscribers including RACQ.

Fig. 2 shows the data flows between QMR, BOM and RACQ in this implementation.
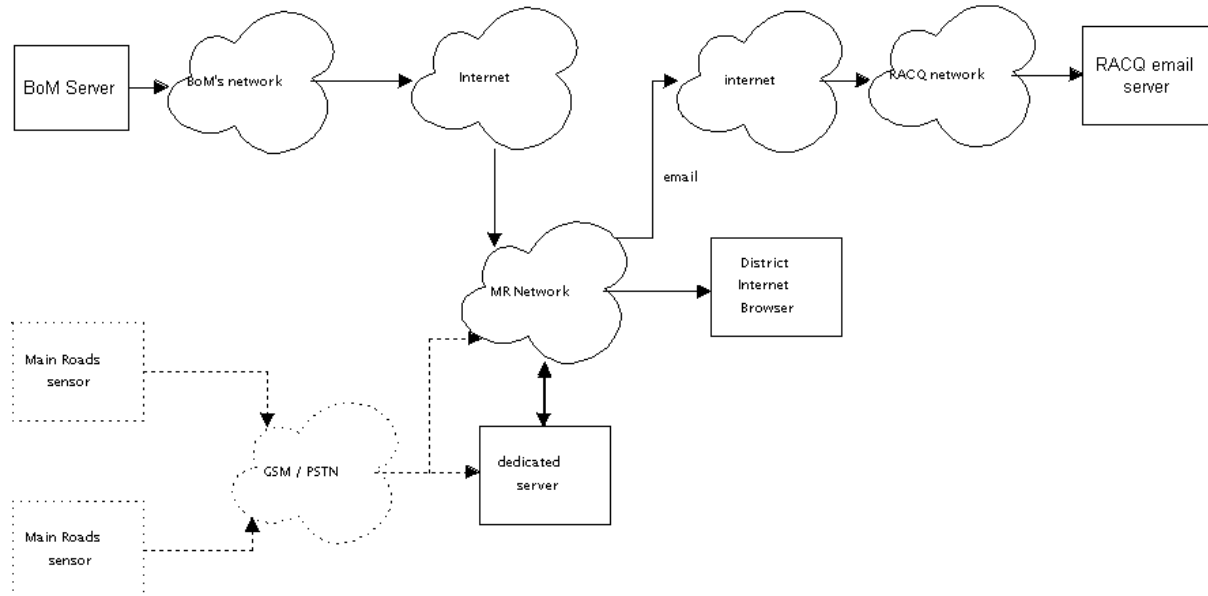

Fig. 2: Pilot Implementation

The "dedicated server" block as shown in Fig. 2 is the core of this system. It consists of three functional modules, namely: "Data Acquisition & Processing" module, "Sensor Interface" module and "Web server" module.

The "Data Acquisition & Processing" module is responsible for acquiring data from BOM and in the future from QMR's own sensors. The Processing component of this module performs the tasks of the "Correlation algorithms" and "decision logic" blocks as described in Fig. 1.

The "Sensor Interface" module will be needed in the future to connect QMR's sensors with the "Data Acquisition & Processing" module. When this happens, the "Data Acquistion & Processing" module will be expanded to include the functionality of the "Forecasting model for location with sensors" block as described in Fig. 1.

The "Web server" module has a number of Common Gateway Interface (CGI) web programs written to allow traffic managers to browse the road flood forecasts, edit the forecasts, and authorise the transmission of the forecasts to internal / external subscribers with emails. After RACQ receives the email, the Traveller Information Website (2) is updated accordingly.

Roadside advisory equipments such as traffic signals and VMS are controlled manually via the existing QMR ITS platform called STREAMS (Synergised Transport Resources Ensuring and Advanced Management System) by traffic managers as STREAMS already has this functionality.

OPERATIONAL IMPLEMENTATION

The Operational Implementation adopts a "Distributive Computing" approach. It builds upon STREAMS that also adopts a "Distributive Computing" approach. The STREAMS platform includes incident management capability. The reason for adopting the "Distributive Computing" approach is that it allows individual QMR Districts to look after their own areas while sharing selected information with other Districts is possible.

This implementation comprises a suite of softwares (shown as "Application Suite for Districts" in Fig. 3) installed in every STREAMS processor in every QMR District cooperating with existing functional modules. The software suite is an extension of the existing STREAMS suite of softwares. Each installation operates independently at District level acquiring data from BOM that are only relevant to their own use. Selected data of each installation are shared within QMR. Access to forecasts by external stakeholders, such as RACQ, will be via the telecommunication services provided by STREAMS, and the control to traffic signals and VMS is achieved through STREAMS with the traffic manager's interaction as part of the data quality control process.
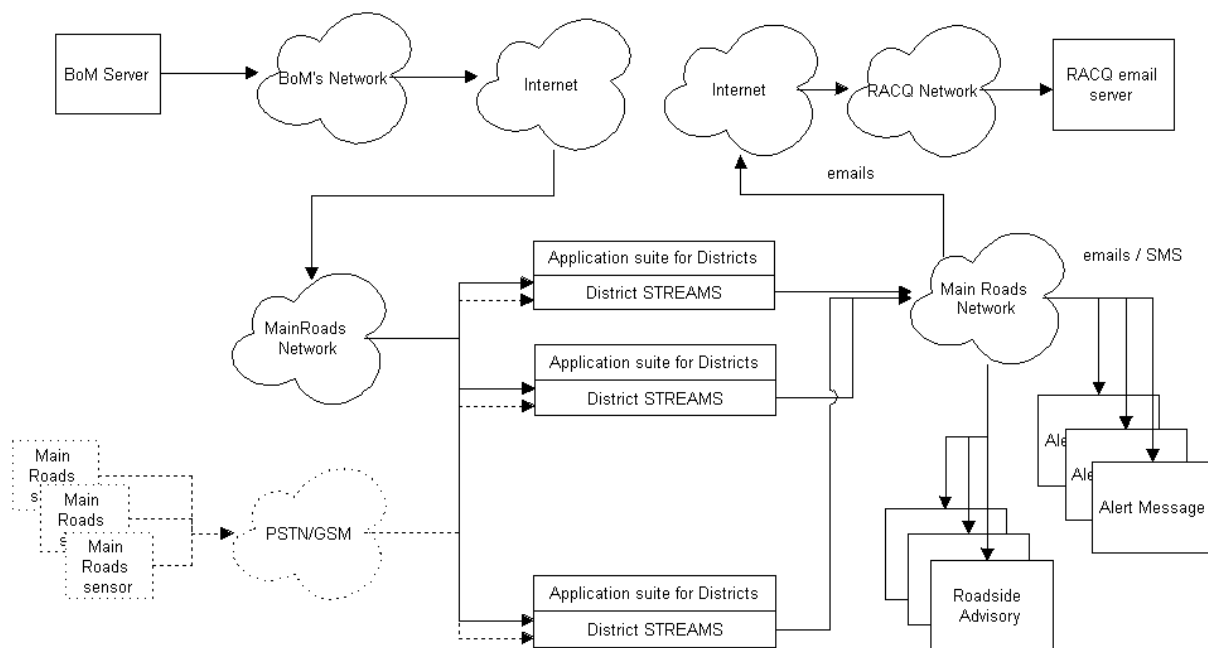

Fig. 3: Operational Implementation

The "Application suite for Districts" block has three major functional modules: "Data Acquisition & Processing" module, "Sensor Interface" module, and "Browsing and Editing tools".

The "Data Acquisition & Processing" module and the "Sensor Interface" module in the Operational Implementation perform the same tasks as those in the Pilot Implementation except that the Operational Implementation intends to acquire data that are only relevant to the District itself whereas the Pilot Implementation is a state-wide system.

The "Browsing and Editing Tools" module allows QMR traffic managers to browse hydrographs in textual and graphical formats, as well as to edit Road Closure Forecasts before publishing them.

This implementation has the following characteristics:

- One suite of softwares runs everywhere.
- Individual QMR Districts' traffic control centres configure their own systems to fetch hydrographs from BOM that are only relevant to their own operation.
- If any additional sensor is installed by QMR, individual QMR District is responsible for polling and responding to their own sensor.
- "Forecasting models" and "Correlation algorithms" are developed, controlled and owned by individual Districts.
- Road Closure Forecasts are shared and accessible from within QMR.
- STREAMS provides email and SMS to internal and external subscribers including RACQ.
- Online traveller information is provided through RACQ traveller information website.
- Roadside traveller information is provided by STREAMS through traffic signals and VMS.

CONCLUSION

Once in place, the RFWS will provide real-time and predictive road flooding information to Queensland road users and QMR traffic managers.

By accessing the RACQ's Traveller Information Website, road users will be better placed to plan for alternative routes by having an estimate of likely duration of flooding. More importantly, the system has the potential to avoid transport disruption and improve road safety in region and rural Queensland.

Operationally, by providing sufficient time in advance to traffic managers of imminent flooding, the efficiency of the decision making process to close a road before, and re-open it after, flooding will be improved. The system will also provide the opportunity to automate the road closure and reopening process through the integration of real-time flood information and various roadside infrastructures via QMR's ITS platform, STREAMS.

REFERENCE

(1) QUEENSLAND FLOOD SUMMARY 1990 – 1999, http://www.bom.gov.au/hydro/flood/qld/fld_history/floodsum_1990.shtml

(2) *RACQ Traveller Information Website*, http://www.racq.com.au/cgi-bin/0213_main_map.cfm

(3) New South Wales Government (1986) *Floodplain Development Manual*, ISBN 724030115.

(4) *River Level Forecaster*, http://www.ccg.leeds.ac.uk/simon/intro_b.html

(5) *Bureau of Meteorology Website*, http://www.bom.gov.au